**International Journal of Applied Power Engineering (IJAPE)**
Vol. 1, No. 3, December 2012, pp. 129~144
ISSN: 2252-8792 

# Compensation of Single-Phase and Three-Phase Voltage Sag and Swell Using Dynamic Voltage Restorer

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**Article Info**

***Article history:***

Received Jul 25, 2012
Revised Nov 10, 2012
Accepted Nov 16, 2012

***Keyword:***

Average detection method
DVR
Fast detection algorithm
Voltage sag
Voltage Swell

**ABSTRACT**

DVR is a equipment which was connected in series and adjusting the loading voltage by feeding the voltage in system. The first installation was in 1996. Usually DVR installed between sensitive loads feeder and source in distribution system. The main duty, fast support load voltage (by fast detection algorithm) during disturbance to avoid any disconnection. In this paper approaches to compensate for voltage sag and swell as a common disturbance in voltage transmission and distribution networks is presented. A dynamic voltage restorer based on the dq0 algorithm for three-phase and dynamic voltage restorer based on the average detection method for single-phase are discussed, also in this paper we compare the two methods used to compensate the single-phase and three-phase process. Result of three-phase and single-phase voltage sag and swell simulation has been presented by MATLAB/SIMULINK.



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## 1. INTRODUCTION

Any variation in voltage, current and frequency quantities, which causes damages or inaccurate performance of using equipments, is recognized as disturbance power quality. One of the Phenomenon of power quality voltage flash is, the decreas of voltage magnitude with short period (0.5 cycle to one minute), the reason is the short circuit in network or installation of high capacity motors (Generator) which many problems for electricty manufactuer. The main reason of attention to power quality is economical subjects. Various actions can be used by manufactuer, customers and equipments produces to decrease the quantity and severity voltage sags and reducing the sensitivity of equipments during voltage sags, the preventing in lowest level near to load is the cheapest way for restoring. One of the solutions to improve the power quality is using of FACTS-Devices in distribution system. Dynamic voltage restorer (DVR) is one of the device which is connect series to network and near to Customer by feeding three-phas AC controlled voltage, restore voltage sag immediately[1]. In this paper, the solution to restore voltage sag and swell (As a common disturbance in the distribution network) has been presented by DVR. In this paper, approaches for compensating the voltage sag as a common disturbance in voltage distribution networks is presented. After introduction in second section, the restoring methods for voltage sag which are using in distribution system has been pointed. In the third section, to introduce the modeling one of the newest and most efficient way in series compensated distribution network called dynamic voltage compensator (DVR) has been discussed. The fourth part of this paper introducing control algorithm based on SRF.The simulation model by the software MATLAB / SIMULINK given in section 5. Is given in Section 6, circuit function and simulation result. Finally, conclusion and summarized of all the subjects in this paper is given in Section 7.

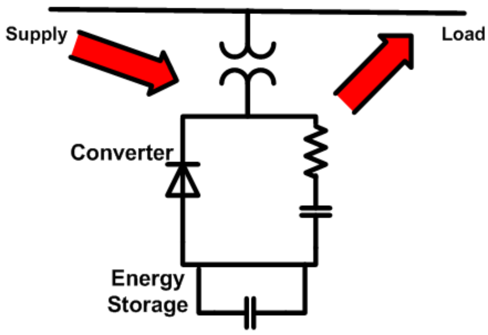


Figure 1.General plan of the DVR[2]

## 2. METHOD OF RESTORING FOR VOLTAGE SAG

In this part the methods and related defects has been presented.

### 2.1. Tap Changing Transformers

Electronic tap changing is achieved via the use of back to back thyristors (SCR) with a tap changing transformer. Has a reasonable response time (1 cycle) and is popular for medium power applications (>3kVA). However, high control resolution requires large number of SCRs. the control for fast response becomes fairly complex. Another drawback of this scheme is its usceptibility to high transient current with motor loads upon tap changing and its poor transient voltage rejection[2].

### 2.2. Saturable Reactor Regulators

This plan is simple and output voltage can be controlled by changing the impedance of saturater reactor. One of the problems is slow response (10 cycle) and high out impedance which makes distrurbance in non linear sensitive loads in coefficent load power factor[2].

### 2.3. Phase Controller Regulators

This technique uses phase controlled thyristors with LC filter to control output voltage. It has a slow response, high distortion especially with non-linear loads, over sized filters, very poor input line harmonics and will not handle surge currents such as motor starting[2].

### 2.4. Electronic Voltage Regulators

They are a new class of automatic voltage regulators based on high frequency switching inverter technology. It can provide fast response (1-2 ms), sinusoidal voltages, and compact design [2].

### 2.5. Static Voltage Regulators (SVR)

This device, through the use of static tap changers, simply regulates the voltage to equipment operational levels. The SVR is able to correct voltage sag conditions (a 55% of the normal voltage maximum depth) in a quarter of a cycle (4 ms), to allow even the most sensitive manufacturing equipment to ride through voltage sag conditions caused by faults in the utility distribution or transmission systems [2].

### 2.6. Ferroresonant Transformers (CVT)

Ferroresonant transformers, also called constant-voltage transformers (CVT), can handle most voltage sag conditions (always beneath 20 kVA). The ferroresonant regulator has a response time of about 25 ms or 1.5 cycles. More important are its high output impedance (again up to 30% of load impedance), sensitivity to both leading and lagging load power factors, and low efficiency at partial loads. In summary, the ferroresonant regulator is useful in small systems that do not contain large motors[2].

### 2.7. Dynamic Voltage Restorer (DVR)

This method immediately restorer and clear the voltage sag, quick response (< 1 ms), low waste conductivity switching is the main specifications[2].

## 3. DVR INTRODUCTING

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [2], [5]. The discussion can be made in several sub-chapters.

Dynamic Voltage Restorer is a series connected device that injects voltage into the system in order to regulate the load side voltage. The DVR was first installed in 1996. It is normally installed in a distribution system between the supply and the critical load feeder. Its primary function is to rapidly boost up the load-side voltage in the event of a disturbance in order to avoid any power disruption to that load there are various circuit topologies and control schemes that can be used to implement a DVR. In addition to its main task which is voltage sags and swells compensation, DVR can also added other features such as: voltage harmonics compensation, voltage transients' Reduction and fault current limitations The general configuration of the DVR consists of a voltage injection transformer, an output filter, an energy storage device, Voltage Source Inverter (VSI), and a Control system as shown in Figure 2.[3],[4],[5].

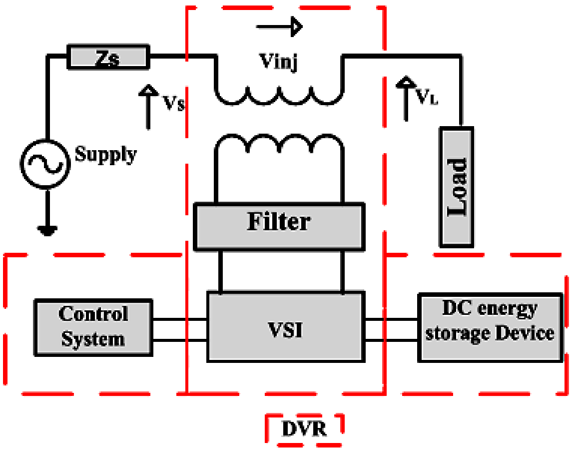


Figure 2. Structure of DVR[3]

1. **Voltage Injection Transformer**: The basic function of this transformer is to connect the DVR to the distribution network via the HV-windings and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage. The design of this transformer is very crucial because, it faces saturation, overrating, overheating, cost and performance. The injected voltage may consist of fundamental, desired harmonics, Switching harmonics and dc voltage components. If the transformer is not designed properly, the injected voltage May saturate the transformer and result in improper operation of the DVR [3], [6].
2. **Output Filter:** The main task of the output filter is to keep the harmonic voltage content generated by the voltage source inverter to the permissible level (i.e. eliminate high frequency switching harmonics).It has a small rating approximately 2% of the load VA [3], [6].
3. **Voltage Source Inverter:** A VSI is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, Magnitude, and phase angle. In the DVR application, the VSI is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing [3], 6].
4. **DC Energy Storage Device:** The DC energy storage device provides the real power requirement of the DVR during compensation. Various storage technologies have been proposed including flywheel Energy storage, super-conducting magnetic energy storage (SMES) and Super capacitors these have the advantage of fast response. An alternative is the use of lead-acid battery, Batteries were until now considered of limited suitability for DVR applications since it takes considerable time to remove energy from them. Finally, conventional capacitors also can be used [3], [6].
5. **Control system:** The aim of the control system is to maintain constant voltage magnitude at the point where a sensitive load is connected, under system disturbances [3], [6].

## 4. CONTROL ALGORITHM BASED ON SYNCHRONOUS REFERENCE FRAME

Figure 3 is a simplified circuit for modeling the fault event within the power system. The utility grid is modeled by a balance three-phase voltage source and its system impedance is represented by Ls. $C_{PF}$ represents the power factor correction capacitors installed in the grid. The resistors $R_F$ connected to feeder 1 is to create single-phase or three-phase ground faults. A voltage compensator is serially connected in feeder 2 which feeds the critical loads. Under normal condition, the bypass switches are closed and the critical loads are directly fed by the utility. When voltage sags occur, magnitude of feeder 2 voltages Vsabc will drop below normal level because large fault current flowing through Ls causes extra voltage drop[7].

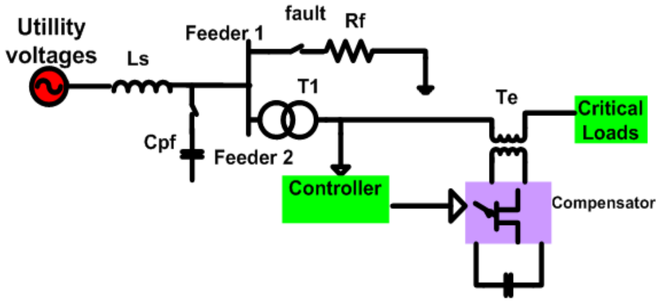


Figure 3.Simplified circuit modeling fault sag in the power system[7]

First step to in all methods of restoring the voltage sag fast detetion enable us to restor the voltage sag aprompty. A fact detection algorithm based of SRF has been shown in figure 4.

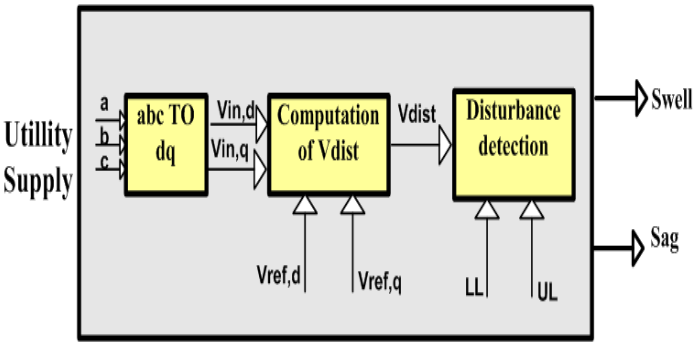


Figure 4. Block diagram of fast detection algorithm based on conversion of SRF[10]

The disturbance detection algorithm must achieve two important functions to ensure proper operation:

1. Regardless of the nature of the voltage disturbance (sag or swell, either balanced or unbalanced), the algorithm should be able to detect the disturbance immediately.
2. Should be able to recognize when the amount of the voltage disturbance is beyond certain limits and then deliver a trip signal, otherwise consider the system operating under normal conditions. As an example, sags and swells of 2% or 3% should not be considered conditions out of tolerance[8].

First stage of detection algorithm is converting the input voltage from abc to dq (static and synchronous dq), the all linear frequency detection has been omitted and dc value for dq unsteady is remaind this change will be caculated as :

$$\begin{bmatrix} V^s_{S_d} \\ V^s_{S_q} \\ V^s_{S_0} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\omega t & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t - \frac{2\pi}{3}\right) \\ \sin\omega t & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t - \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} V_{S_a} \\ V_{S_b} \\ V_{S_c} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} V^e_{S_d} \\ V^e_{S_q} \end{bmatrix} = \begin{bmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{bmatrix}\begin{bmatrix} V^s_{S_d} \\ V^s_{S_q} \end{bmatrix} \quad (2)$$

Note that the frequency $\omega$ of the utility grid can be obtained by a phase-locked loop (PLL) circuit. This circuit is applied to produce sinusoidal wave in same phase with grid main voltage. Under normal conditions, the utility voltages $V_{s_a}$ ,$V_{S_b}$ and $V_{S_C}$ are three-phase balanced. After being transformed into the synchronous reference frame, their synchronous reference frame counter part $V^e_{sq}$ *and* $V^e_{sd}$ become DC quantities.

These values are filtered and stored as references $V^{e*}_{sq}$ *and* $V^{e*}_{sd}$. The references are continuously updated to monitoring utility voltages. If voltage sags occur, the latest update of the references will be locked and used as a basis to calculate the compensation command.

When voltage sags occur, the inverter needs to inject the difference between the faulted utility voltage and the desired balanced load voltages to maintain the load voltage at the level of normal condition [7]. Thus the inverter command voltages $V^{e*}_{inv_q}$ and $V^{e*}_{inv_d}$, are calculated as follows:

$$V^{e*}_{inv_q} = V^{e*}_{s_q} - V^{e}_{s_q} \tag{3}$$

$$V^{e*}_{inv_d} = V^{e*}_{s_d} - V^{e}_{s_d} \tag{4}$$

Then the order voltage convert to abc form to produce requiered pulse for inverter gate by sinusoidal pulse wide modelation. The analisys of wave shape is shown that signals of is valued from calculation in addition the sag or swell problem can by specified by these signals so:

$$V_{dist} = V^{e*}_{inv_q} \tag{5}$$

Where $V_{dist}$ is the magnitude of the vector that represents the instantaneous deviation of utility input voltages respect to the given reference[7].

Usually the dq value must be equal to refrence value. If this condition happens the value of $V_{dist}$ is zero. Other wise $V_{dist}$ is a DC signal can be change with tribulation[7]. If three-phase disturbance happens $V_{dist}$ is absolute DC voltage. In two-phase disturbance $V_{dist}$ is dc voltage with low ripple and in single-phase is swinger DC signal between zero and max value. when voltage sag happens the positive sequence component of grid voltage decreases and the magnitude of positive sequence component calculated as below:

$$V_{pos} = \sqrt{\left(\overline{V^{e}_{s_q}}\right)^2 + \left(\overline{V^{e}_{s_d}}\right)^2} \tag{6}$$

So , $V_{pos}$ compare with $V_{th}$. The compensation inverter will be started if the positive sequence magnitude $V_{pos}$ dropped below a preset threshold level $V_{th}$ . The threshold level is determined by the voltage magnitude at normal condition and a threshold constant k:

$$V_{th} = K\sqrt{\left(V^{e*}_{s_q}\right)^2 + \left(V^{e*}_{s_d}\right)^2} \tag{7}$$

k can be set between 0.0 to 1.0 depending how sensitive the critical loads are to voltage sags.
By monitoring the magnitude of the positive sequence component, voltage sags can be promptly and clearly identified[7].

## 5. SIMULATION

### 5.1. Three-Phase

To check the DVR effects the system has been simulated as figure 5 by MATLAB/ SIMULINK software. In this circuit, a Three-phase fault in Bus B1 occure in 0.15 second which causes %75 voltage sag during 0.2 second And restores in 0.35 second by safely devices. also Figure 5, Circuit for detecting and compensating swell with little change we can instead of Three-Phase Fault block, using Three-Phase Programmable Voltage source block.

By this block, a 20% increase in the voltage range in the period 0.15-0.35 seconds to get there. Change in the polarity of transformers, circuit of Figure 5 is able to compensate the voltage is increased. Parameters and circuit elements is similar to the circuit in Figure 5 and is only dc voltage applied to the inverter 1KV. This circuit restores the voltage of sensitive loads in Bus B2 with feeding suitable voltage by inverter system during fault. The total time of simulation is 0.5 second .As mentioned before, the first step in all methods to restore voltage sag, is the fast detection of disturbance. It is the duty of the block SAG DETECTOR. The sag detector block receive the three-phase voltage of Bus B1,B3 as input the during voltage sag calculated the controller signal for PWM function, the system model and control cicuit is shown in figure 5,6.

This circuit contain, three-phase inverter and each power switches has one IGBT and reverse-paraller diod to transit current in two side of switch**.**

### 5.2. Single-Phase

In Figure 7, the model of circuit for single-phase voltage detection and compensation sag are depicted. As can be seen for compensation single-phase disturbance, three single-phase inverter bridge instead of a three-phase inverter is used. also three single-phase breaker for connection inverter output to transformer has been used since the time of the single-phase voltage sag should be closed single-phase Breaker faulty, and two healthy phases breakers remain open. Also for detecting the disturbance occurrence time, conversion dqo unused. This converts when, the voltage and current disturbance that are balanced cause simplifies the control system and reduce the detection time, because at balance disturbance, the output of this converts is DC, but in the single-phase disturbance, conversion of dq does not show variation of values moment DC. So the output of this convert has a ripple component 100 HZ which has twice the frequency of the voltage source. Thus to achieve the DC values, needed low-pass filter or filter slot 100HZ. But these filters causing delays in voltage detection and eventually time detection will increase. Thus in detection of unbalanced disturbance, other detection methods such as average, RMS or peak is used[9]. In the circuit of

Figure 7, Difference per-unit values method have been used. Block inverter system is shown in Figure 8. In this circuit, a single-phase fault in Bus1 occure in 0.15 second which causes %75 voltage sag during 0.2 second And restores in 0.35 second by safely devices. also Figure 7, Circuit for detecting and compensating swell with little change. By this block, a 20% increase in the voltage range in the period 0.15-0.35 seconds to get there. Change in the polarity of transformers, circuit of Figure7 is able to compensate the voltage is increased. The total time of simulation is 0.5 second.

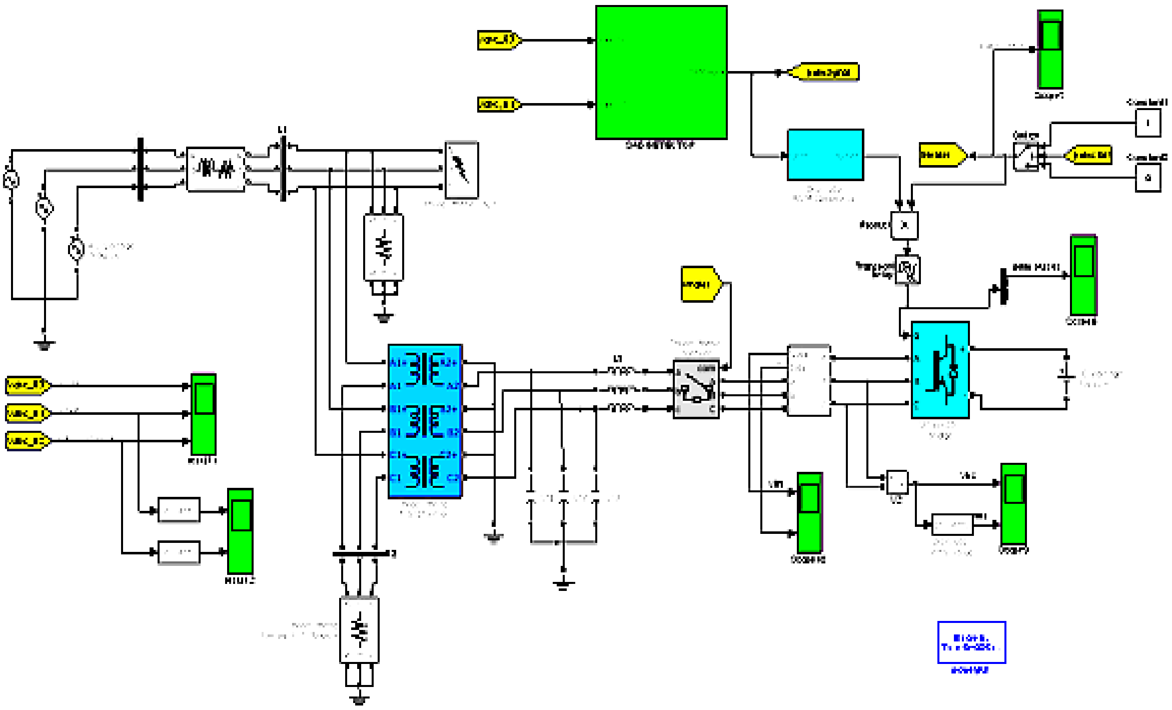

Figure 5. Modeling circuit for Detecting and compensating voltage three-phase sags and swell in MATLAB / SIMULINK

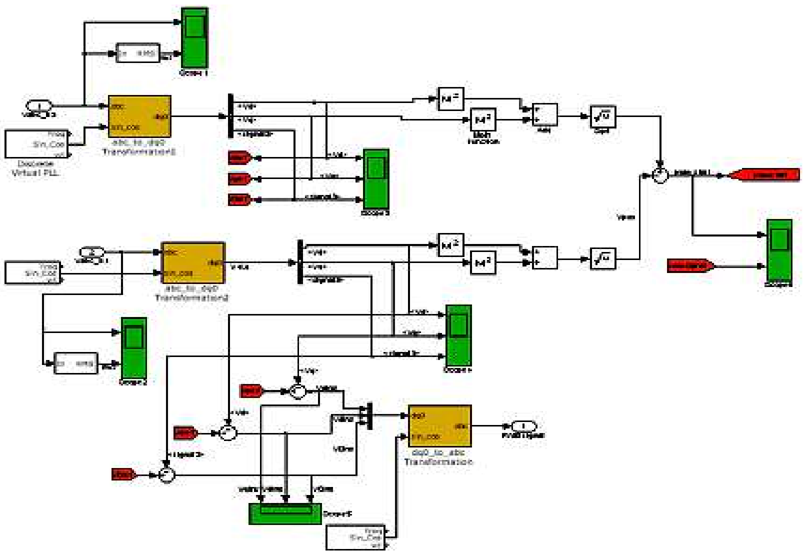

Figure 6. The control circuit block of SAG DETECTOR

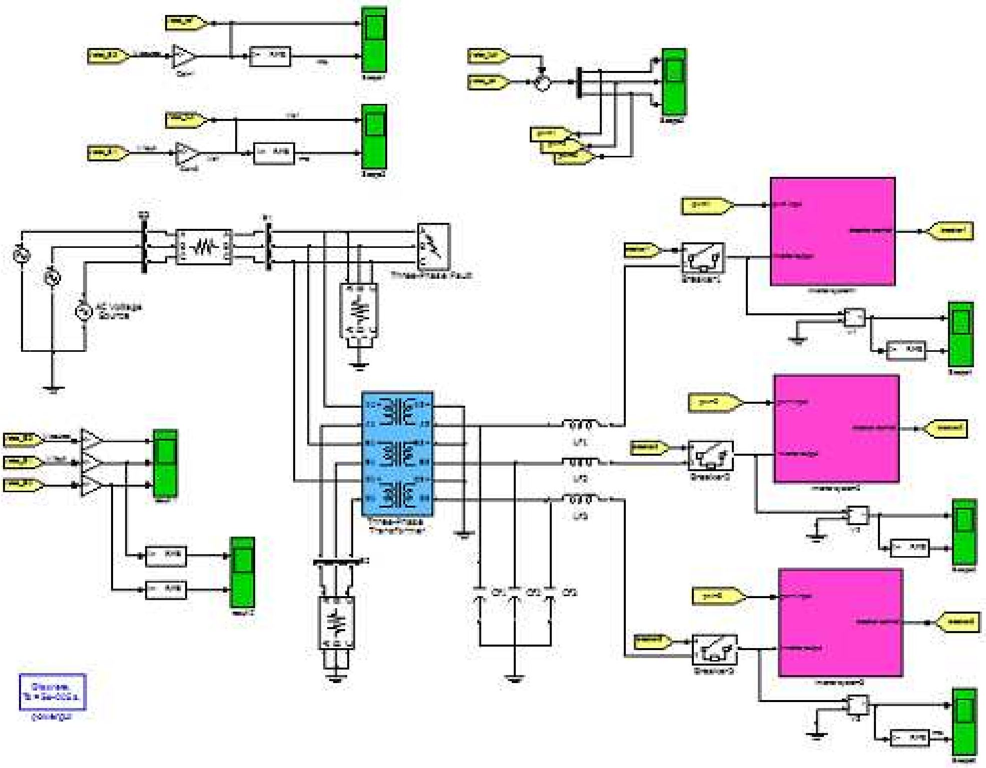

Figure 7. Modeling circuit for Detecting and compensating voltage single-phase sag and swell in MATLAB / SIMULINK

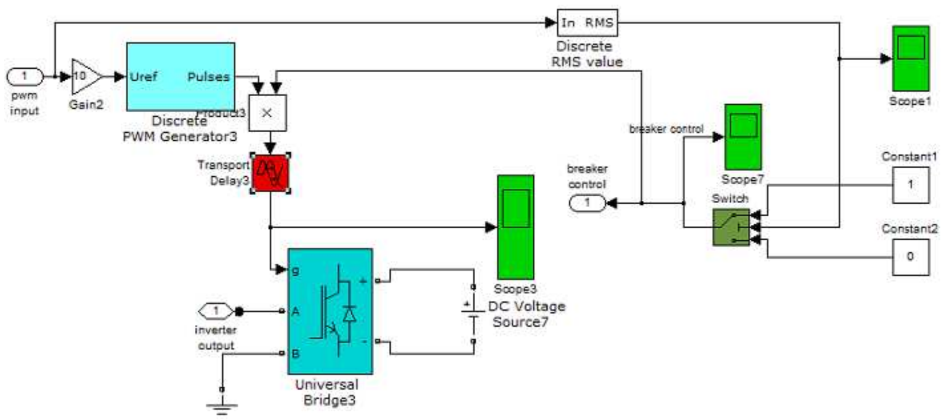


Figure 8. The Inverter System block diagram in MATLAB / SIMULINK

Table1. Circuit parameters

| Parameter | Value | |
|---|---|---|
| | Single-phase | Three-phase |
| Main Supply Voltage per phase | 200 V | 200 V |
| Supply Voltage DC | 160 V | 270 V |
| Line Frequency | 50 HZ | 50 HZ |
| Series transformer turns ratio | 1:1 | 1:1 |
| Line Impedance | $L_S$=0/5 mH | $L_S$=0/5 mH |
| | $R_S$=0/1 Ω | $R_S$=0/1 Ω |
| Load Impedance | 40Ω | 40Ω |
| A saw-tooth carrier wave frequency | 1800 HZ | 5400 HZ |
| K | 1 | 1 |
| Filter Inductance | 4mH | 1mH |
| Filter capacitance | 10μF | 10nF |

### 5.3. Parameters and Element of Circuit
In Table 1 parameters and constant factors in simulated circuit is mentioned.

## 6. CIRCUIT FUNCTION AND RESULT
### 6.1. THREE-PHASE
as shown in figure 5, the three-phase source voltage in Bus B3 is the Measurement refrence voltage and stored which result are in figure 9. Then the refrence voltage transfer from abc to dqo. In Balanced three-phase disturbances, after changing dqo, voltage are absolute DC. this transfer make easier the control circuit so the detection time can be decreased. Bus B1 voltage as Under disturbance voltage are calculated and change to dqo form. shape of voltage shows the fault point before and after of Transfer. as you can see in figure10,circuit have ripple in start and finish of disturbance, about to a cycle is a ripple after reaching to steady-state the circuit function is acceptable. according to figure11,when three-phase balance disturbance happens, after reaching Steady-sate condition $V_d$ ,$V_q$, are absolute DC.

According to figure 12, upon voltage sag, $V_d$ , $V_q$ are higher than zero but $V_o$=0, then voltages convert from dq0 to abc form to have $u_{ref}$ for PWM generator block. PWM signal is output of SAG DETECTOR block. On the other hand, in this block by using refrence voltage and measurment voltage in dq0 reference the $V_{pos}$ and $V_{th}$ can be calculated and the difference of them, the voltage sag time clarifies. in figure 13, in voltage sag, required sinusoidal voltage with suitable magnitude for PWM function has been produced. the output sinusoidal voltage of SAG DETECTOR is feeding as input refrence to PWM Generator block, and compare with triangular carrier wave with 5400 HZ frequency and required control pulse for inverter is produced. also PWM start signal change to 0 or 1 signal by using a switch, when input is equal or higher than 0.1 switch has out put to prevent detection of lower 10% voltage sag. This signal (0 or 1) multiplies with PWM generator output then inject to inverter gate. by feeding DC voltage and control pulses to inverter, the required voltage produces for restoring of voltage sag in network, when breaker closed and LC filter omitted noises. this voltage feeds in series network. figure 14 shows the three-phase voltage and current which feedings by inverter, and output linear inverter voltage BC. Finally in figure 21,22,23 and 24 you can see the final result of restoring and control algorithm, which approred simulated circuit to restore three-phases voltage sag and swell. In figure 22 and 24 effective voltage is shown before and after restoring of voltage sag and swell. it is clear that suggested circuit, restores voltage sag and swell.

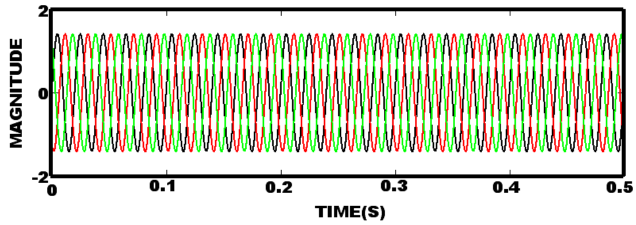


Figure 9. Balanced three-phase voltage source which is stored as a reference voltage

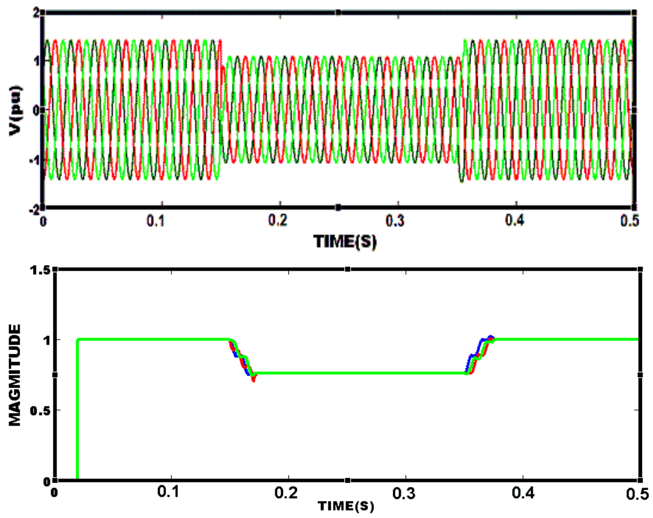


Figure 10. Voltage B1 of Symmetrical three-phase fault and create a voltage sag 75% a) in the form abc b) an effective amount of voltage

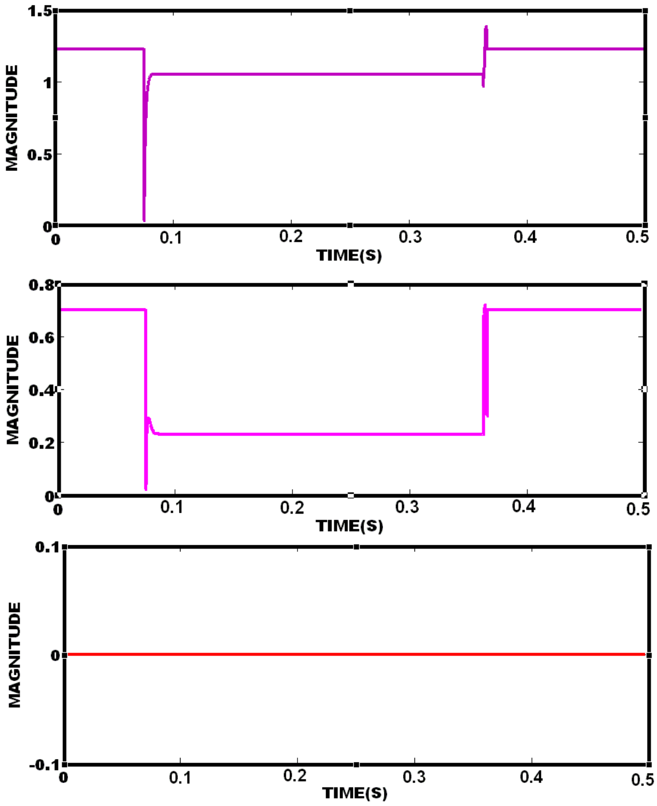


Figure 11. Bus voltages of B1 conversion to form dqo a) Vd b) Vq c) V0

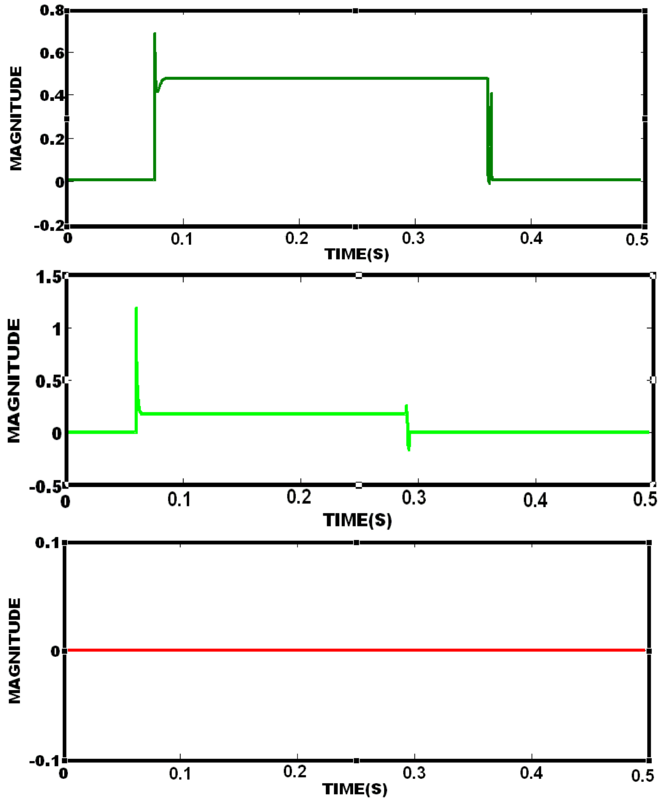


Figure 12. Difference between reference and measured voltages for the PWM control voltage amplitude a) Vdinv b) Vqinv c) V0inv

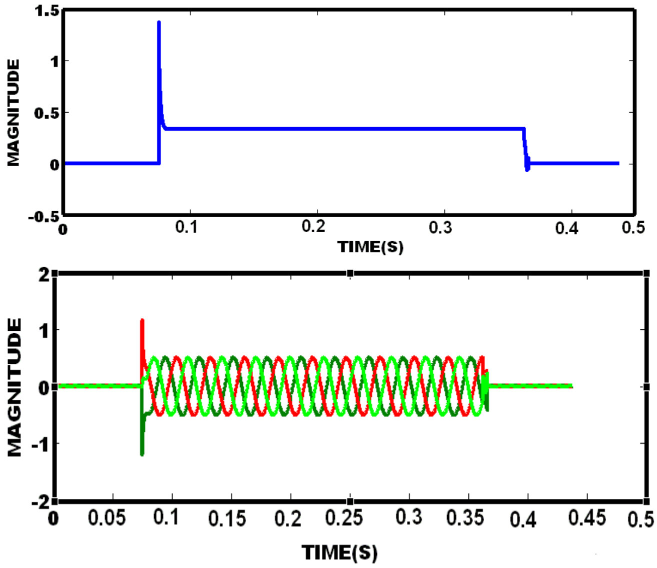


Figure 13. a) difference between Vpos and Vth for detecting the time of the disturbance, b) applied to the PWM wave control Uref

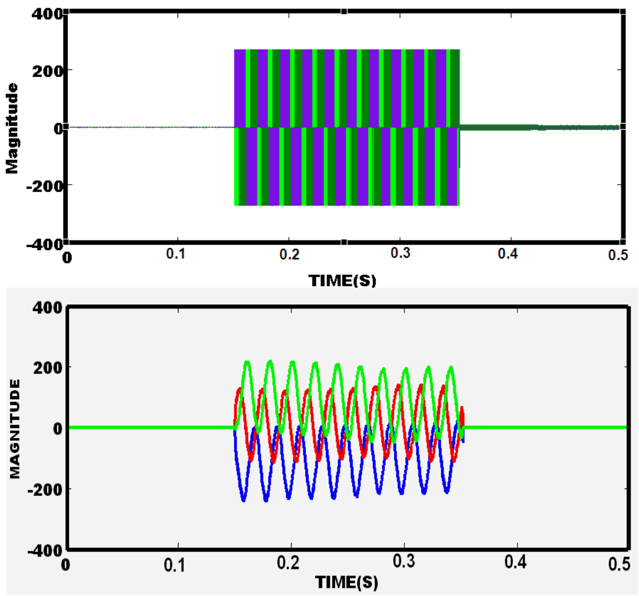


Figure 14. a)voltages b) Three-phase injected currents by the inverter at the time of disturbance

**6.2. Single-Phase**

In this circuit, three-phase voltages at bus B3 as reference voltages to be monitored is shown in Figure 15. Three-phase voltages bus B1 are also recorded as a voltage fault (Figure 16), in this figure clearly be seen that a phase voltage has dropped sharply. Then difference between two voltage as the voltage-controlled PWM is given to the block inverter system that seen in Figure 17, this difference is zero for the two healthy phases. As Was observed in Figure 7, in inverter system block, the input convert to the RMS and then applied to the switch and produce a (0-1)zero signal, Multiplied by the output of the PWM block and injected into single-phase inverter full-bridge gate. Figure 18, show that the effective voltage switch input and output signal for the depressed phase. The requirement to switch output 1, input is equal or higher than 0.1 switch has out put to prevent detection of lower 10% voltage sag. Which can be seen in Figure 18 (b) a delay Breaker result is the same condition. when PWM1 effective voltage is more than 0.1, connected Breaker command is given, Effective voltage switch input and output signals for healthy phases are zero. Figure 19 show that injection pulses to the inverter gate for faulty phase.

At Healthy phases, because PWM input and output switch is zero, input of the inverter gate will be zero, Therefore inverter output is also zero. Because only the faulty phase inverter output to be injected in to the network, in Circuit is used in three Breaker, its order of the zero or one signal a switch to receive, Thus two-phase Breaker healthy, remain open and only the faulty phase Breaker is closed, and Voltage after passing through the filter, is injected by the transformer to the network. Each output of the inverter is shown in Figure 20. The end result of compensation single-phase voltage sag is shown in Figure 25.

Regardless of the transient moments of beginning and end of depression, some ripple can be seen that, after reaching steady conditions, the circuit has been well compensated for depression. Figure 26 show the effective voltage before and after compensation. Finally in figure 27,28 you can see the final result of restoring, which approred simulated circuit to restore single-phases voltage swell.

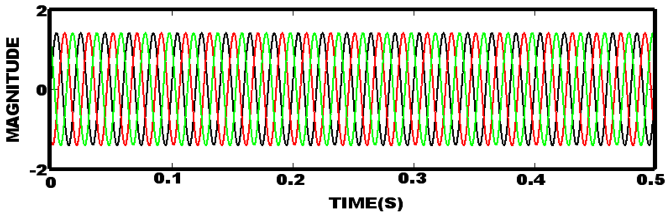


Figure 15. B3 bus voltage as reference voltage

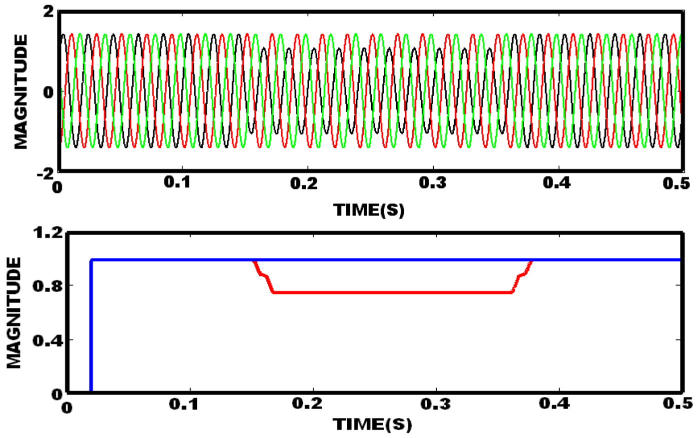


Figure 16. B1 bus voltage under a single-phase voltage sag 75% a) in the form abc b) an effective amount of voltage

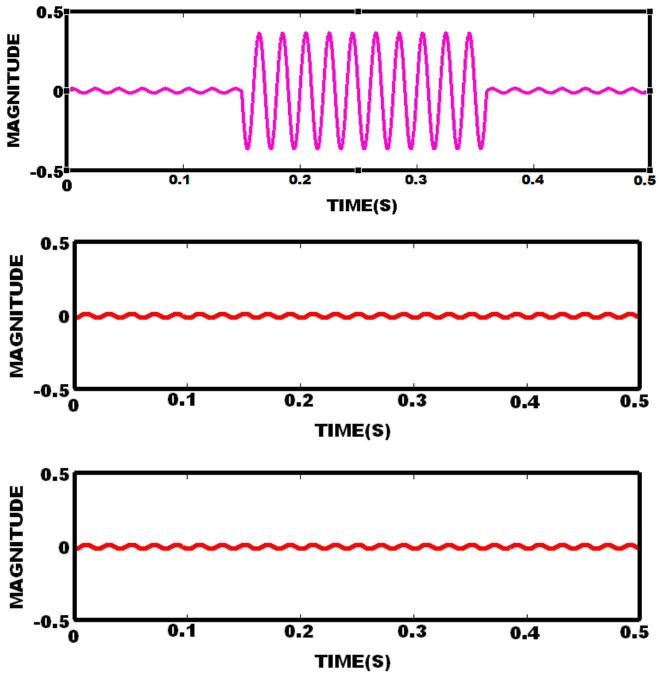


Figure 17. Difference reference voltage and the fault voltage as a voltage controlled pwm a) pwm1 b) pwm2 c) pwm3

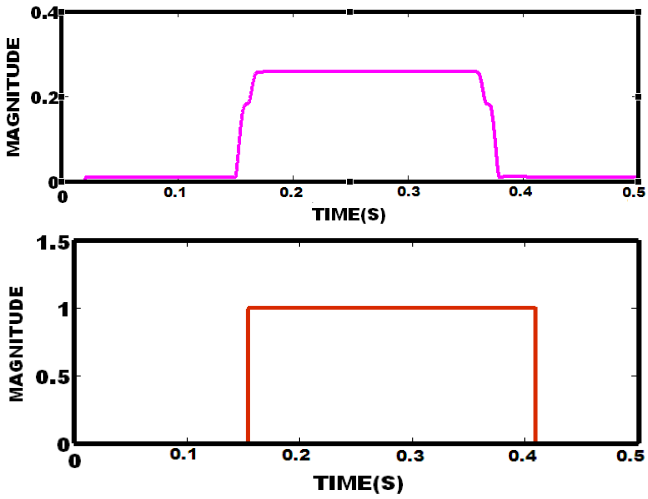


Figure 18. a) an effective amount of the block input inverter system1 b) control signal Breaker in depressed phase

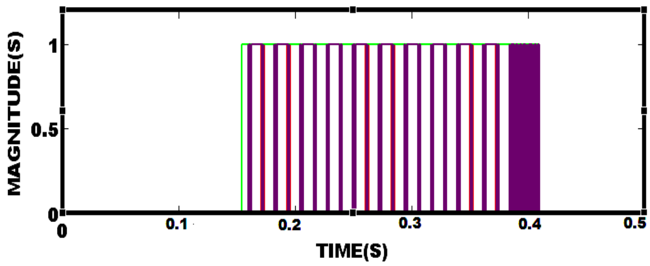


Figure 19. Injection pulses to the inverter gate in a depressed phase

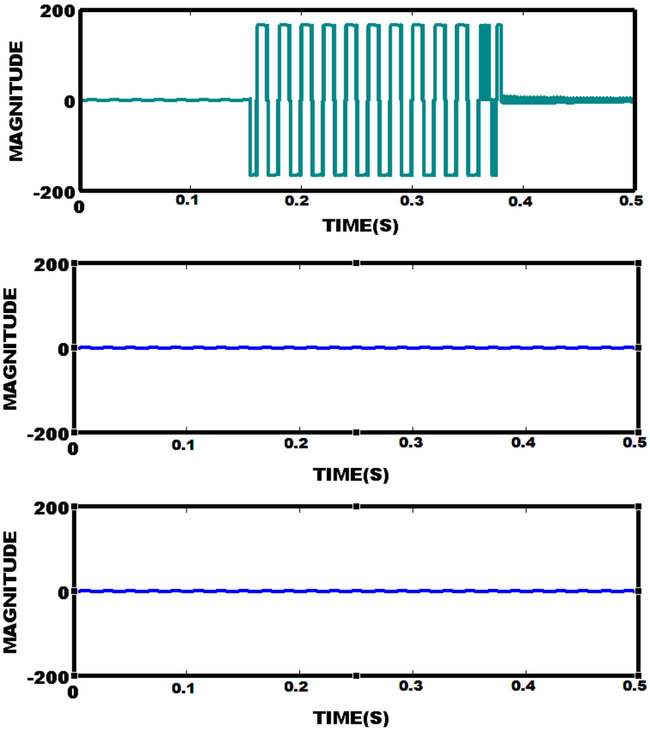


Figure 20. Single-phase inverter output at compensates sags circuit in single-phase a) Vinv1 b) Vinv2 c) Vinv3

Using Series compensator near the critical loads is effective methods to compensate the voltage sags mentioned. In this paper, we were able to analysis the functions of restorer and reached to expected results by modeling various circuits with three-phase and single-phase voltage sag.also we can show that with little changes in this circuit this methods can be used in voltage swell as well. In simulation circuit to restor voltage sag we used changing of abc to dq0,because this change in balance disturbances can make controller easier and decrease the time of disturbance detection, because in balance disturbances the output is absolute DC. But in unbalance disturbances such as single-phase voltage sag because of using additional filters for omitting harmonics of change, the detection time increases, so this method doesnot recommended.therefore in designed circuit to restore single-phase voltage sag,the comparison perunit values is used. results of simulation approres the correct function and expected results in steady-state condition. But in the beginning and end of the transient moments of disturbance, (roughly the size of a cycle) results are not acceptable and will feel the need to further evaluate the circuit.

## 7. CONCLUSION

Detection of voltage sag in network,is the first process for improvement of the power quality. power quality problems contains wide spread range of voltage disturbance, because of various factors in this matter such as magnitude ,frequency, balance,.. detection and restoring is dificault.this variety makes impossible of using for uniqe algorithm. Series restorer which used in transmission and distribution systems is one of the functional method to improvement power quality problems,it is more economical when restorers are near to end user. Using DVR is one of the effective and economical methods for detecting and restoring of voltage sag and can restorer 90% voltage disturbances such as sag,swell and extra voltage,harmonic restorer voltage and asymmetrical voltage balancing systems,also has advantages as fast response,low losses conductivity and low switching. Then fast detection algorithm based on SRF has been introduced to detect three-phase voltage sag and swell.

This algorithm decrease the detection time by transfering abc to dq0 voltage in balance disturbances. The simulation algorithm for three-phase voltage depressions and protrusions were evaluated. All figures showing simulated fast response and full compensation disturbance after crossing the start and end times transient. But in transient moments, the little ripple in the output voltage, can cause trouble for very sensitive equipment that must be considered in future research. In addition, for single-phase compensation the the circuit troughs were presented, in which instead of using the proposed algorithm, compared to values of PU and reference voltages measured at the time of the disturbance took place. For the circuit simulation results also showing that the compensation capability of unbalanced voltage disturbance was effective.

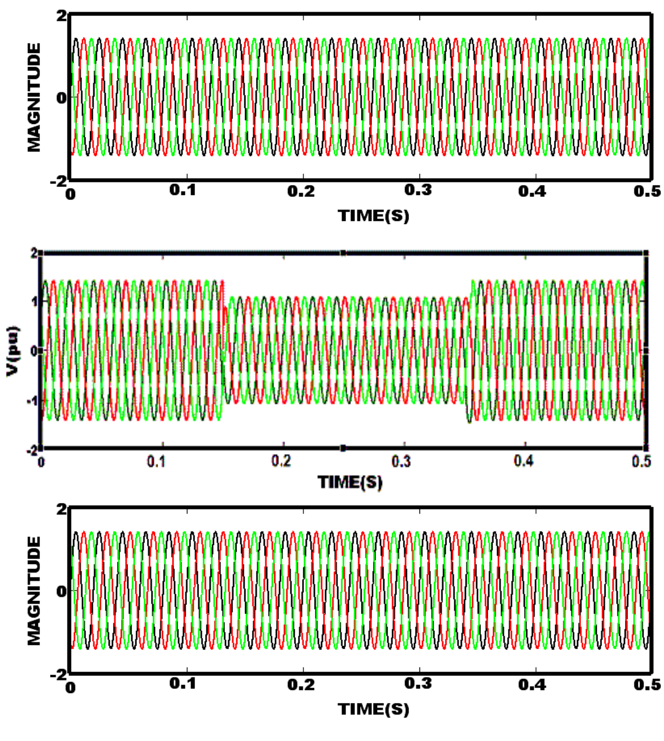


Figure 21. result of three-phase sag a) refrence voltage b) before the compensation c) after the compensation

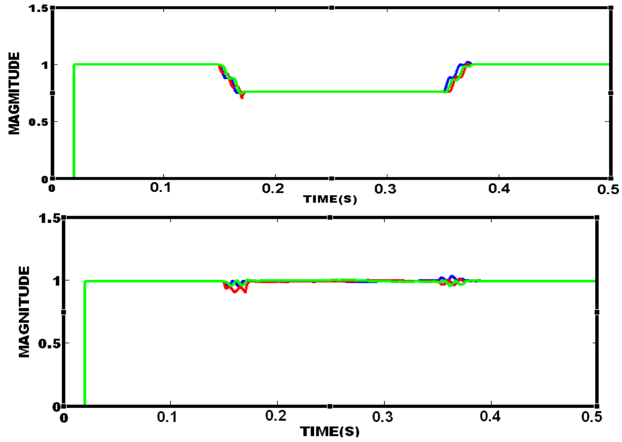


Figure 22. Effective values of voltage at bus B2(sag) a) before compensation b) after compensation

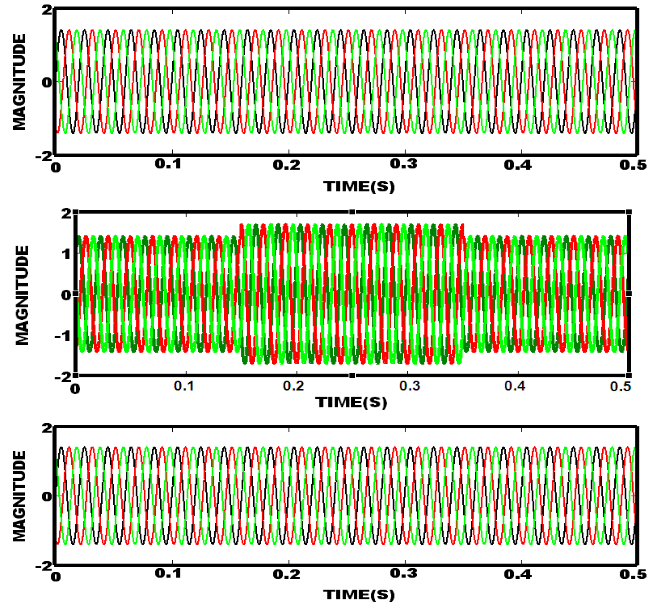


Figure 23. result of three-phase swell a)refrence voltage b) before the compensation c) after the compensation

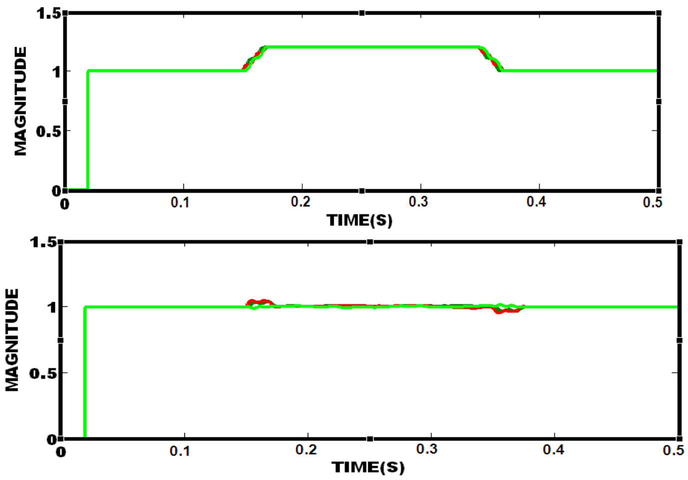


Figure 24. Effective values of voltage at bus B2(swell) a) before compensation b) after compensation

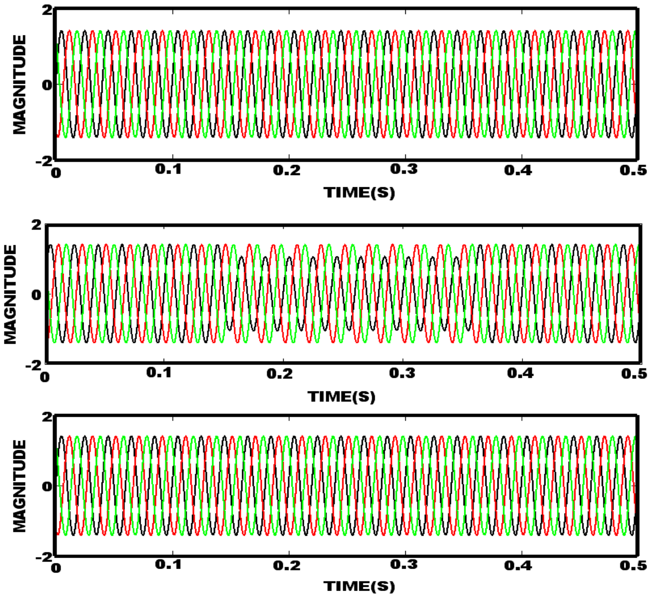


Figure 25. result of single-phase saga) reference voltage b) before compensation c) after compensation

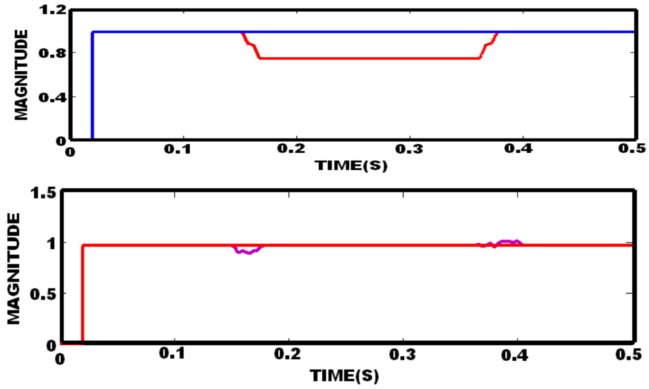


Figure 26. Effective values of voltage at bus B2(sag) a) before compensation b) after compensation

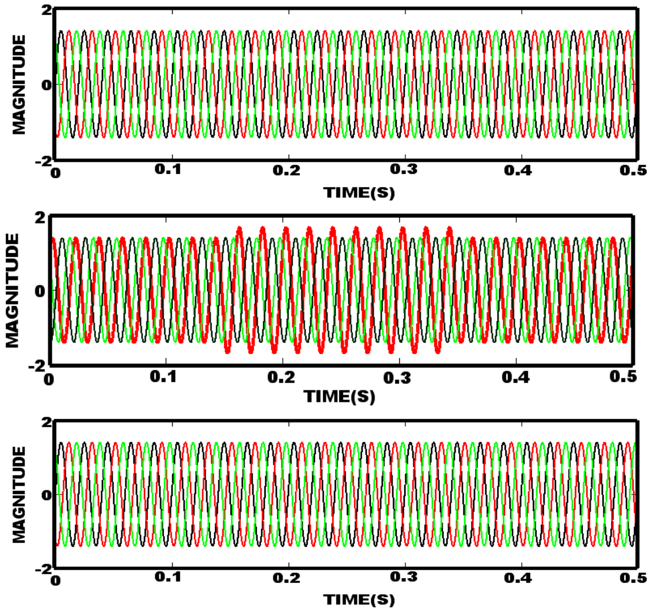


Figure 27. result of single-phase swell a)refrence voltage b) before the compensation c) after the compensation

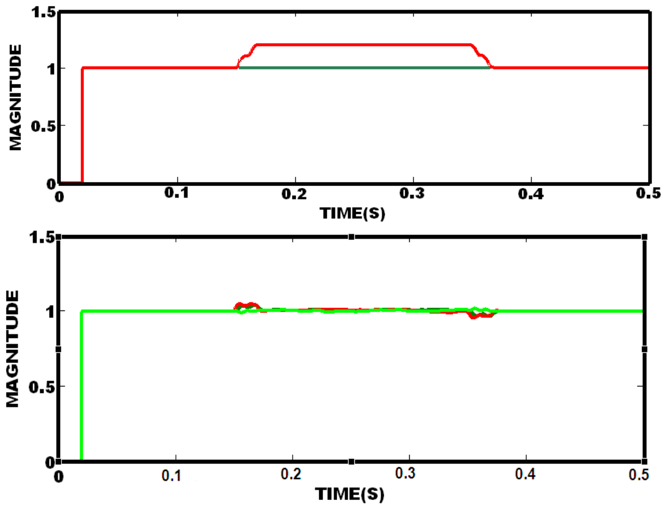


Figure 28. Effective values of voltage at bus B2(swell) a) before compensation b) after compensation

## REFERENCES


[1] Seyyed Hossein Hosseinian, Arif Hello, "power quality", Tehran Regional Electric Company, First Edition, Spring 1383

[2] N.L. Pérez, M.P. Donsión, "Technical Methods for the Prevention and Correction of Voltage Sags and Short Interruptions inside the Industrial Plants and in the Distribution Networks," International Conference on Renewable Energy and Power Quality (ICREPQ'03).

[3] CH SRISAILAM, A SREENIVAS" Mitigation Of Voltage Sags/Swells By Dynamic Voltage Restorer Using Pi And Fuzzy Logic Controller,"International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 4, pp.1733-1737, July-August 2012.

[4] Rosli Omar, N.A Rahim, "Implementation and Control of a Dynamic Voltage Restorer Using Space Vector Pulse Width Modulation (SVPWM) for Voltage Sag Mitigation."

[5] R. Omar, N.A. Rahim, M. Sulaiman, "Modeling and Simulation for Voltage Sags/Swells Mitigation Using Dynamic Voltage Restorer (DVR)," Journal of Theoretical and Applied Information Technology, pp.464-470, 2005 - 2009 JATIT.

[6] T.I. El-Shennawy, A.M. Moussa, M.A. El-Gammal, A.Y. Abou-Ghazala, "A Dynamic Voltage Restorer for Voltage Sag Mitigation in a Refinery with Induction Motors Loads," American J. of Engineering and Applied Sciences, pp. 144-151, 2010.

[7] P.T. Cheng, C.C. Huang, C.C. Pan, S. Bhattacharya, "Design and implementation of a series voltage sag compensator under practical utility conditions," IEEE, 2002

[8] O.C. Montero-Hernández, P.N. Enjeti, "A Fast Detection Algorithm Suitable for Mitigation of Numerous Power Quality Disturbances," Power Electronics IEEE, 2001.

[9] D.M. Lee, T.G. Habetler, R.G. Harley, T.L. Keister, J.R. Rostron, "A Voltage Sag Supporter Utilizing a PWM-Switched Autotransformer," IEEE Transactions on Power Electronics, Vol. 22, No. 2, March 2007.

[10] Oscar C. Montero-Hernández, Member, IEEE, and Prasad N. Enjeti, Fellow, IEEE'A Fast Detection Algorithm Suitable for Mitigation of Numerous Power Quality Disturbances' IEEE Transactions on industry applications,vol.41,no.6,November/december2005.